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Reducing NOx Emissions in Gas Turbine Combustor by Steam Injection Using CLN Technique

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ABSTRACT

One of the most significant emissions of gas turbine is NOx. In present work a gas turbine combustor is simulated with the aim of reducing NOx. In most of researches and industrial cases, steam is injected into combustor separated or premixed with air for reducing NOx emissions. In CLN technique, steam is injected into the combustor premixed with fuel. CFD simulation is done for an axisymmetric non premixed combustor and ability of different combustion models on NOx and temperature prediction is investigated. Results show EDC model which can implement different mechanisms, predicts NOx production more accurate than other models. In addition, influence of injection of premixed steam-fuel into the combustor is investigated and is compared to the injection of premixed steam-air and no steam injection cases. Steam injection into the combustor is done by increasing mass flow rate via increasing the nozzle diameter in constant inlet velocity. Results show that the injection of premixed steam-fuel causes further reduction in NOx and CO production, with respect to other cases.

KEYWORDS:

Gas Turbine Combustor, Numerical Simulation, NOx Reduction, Steam Injection

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1- Introduction

CO is a production of incomplete, and NOx is generated from breaking nitrogen bonds of air in high temperature of combustion chamber. Combustion temperature must be decreased to reduce NOx emission. Air injection, water injection and steam injection are methods that have been introduced as popular methods for reducing combustion temperature and reducing NOx. But it should be noticed that reducing temperature results in incomplete combustion and consequently, increasing CO emission. In the present work, the influence of injection of premixed steam-fuel into the combustor is investigated by using the CLN technique. Results show that the injection of premixed steam-fuel causes further decrease in NOx and CO production in comparison with the injection of premixed steam-air and no steam injection cases.

Turbulence and kinetic interaction is one of the most complicated parts of combustion modeling. In the present work, the influence of different combustion models on prediction of temperature and NOx emission is investigated. Since NO generation strongly depends on kinetic reaction rate, EDC model which can implement different mechanisms predicts NOx production more accurate than other models. In the following section, CFD simulation which is done for an axisymmetric non premixed combustor is discussed.

2- Governing Equation and Numerical Method

Continuity, momentum, energy, and species mass conservation equations, and equation of state for ideal gas are numerically solved to simulate reacting flow in the combustion chamber. Reynolds stresses in momentum equation are determined using standard k-ε turbulence model. Radiation heat transfer equation is solved by using Discrete Ordinate Model (DOM).

3- Geometry and Boundary Condition

Figure 1 shows the geometry of simulated combustion chamber. Numerical simulation of the present work is validated with the experimental study of Garreton et al. [2].

Boundary conditions of the problem are velocity inlet for air and fuel, constant temperature and no slip condition for walls, and pressure outlet for outlet of the combustion chamber.

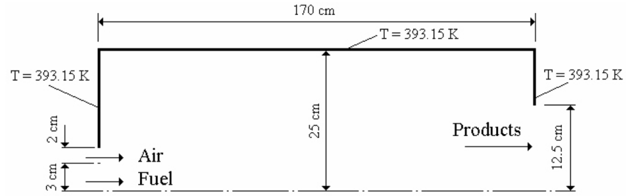

Figure 1. Geometry of combustion chamber

4- Results and Discussion

Figures 2 and 3 respectively show the temperature and NOx mole fraction on the axis of combustion chamber, calculated by different combustion models and compared with experimental data of reference [2].

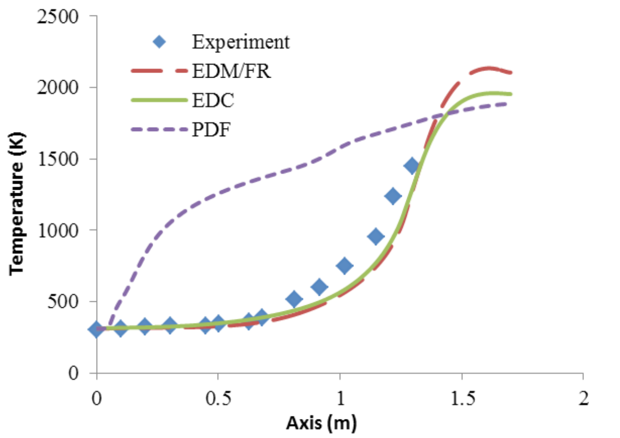

Figure 2. Temperature in axis for different combustion models

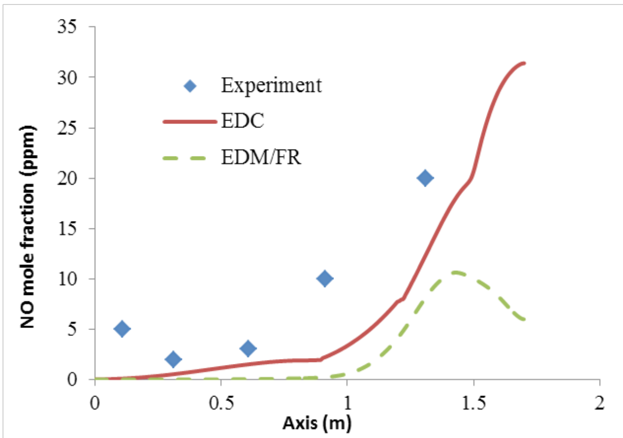

Figure 3. NOx mole fraction in axis for different combustion models

Results show that PDF model is not an appropriate model for simulating this combustion chamber, and EDC model predict NOx emission more accurate than other models.

Figure 4 shows the temperature contour, and Figures 5 and 6 show, respectively, NO and CO mole fractions in combustion chamber for no steam injection, injection of premixed steam-air, and injection of premixed steam-fuel for the ratio of steam mass flow rate to fuel mass flow rate equal to 0.5.

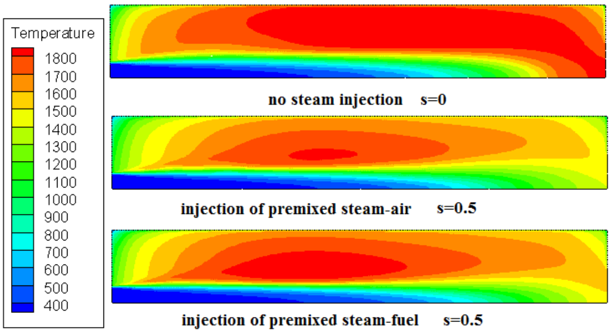

Figure 4. Temperature distribution for three cases of no steam injection, injection of premixed steam-air and injection of premixed steam-fuel

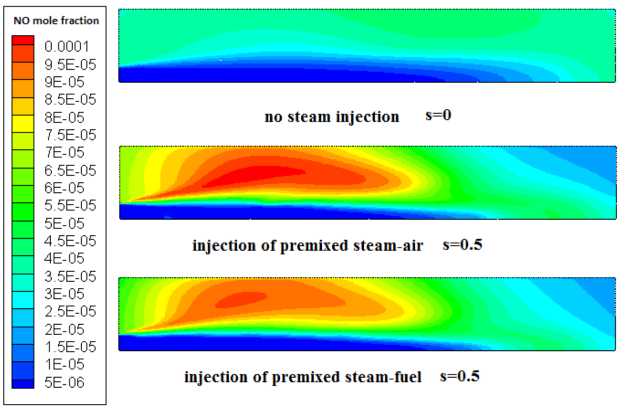

Figure 5. NO mole fraction in combustion chamber for three cases of no steam injection, injection of premixed steam-air and injection of premixed steam-fuel

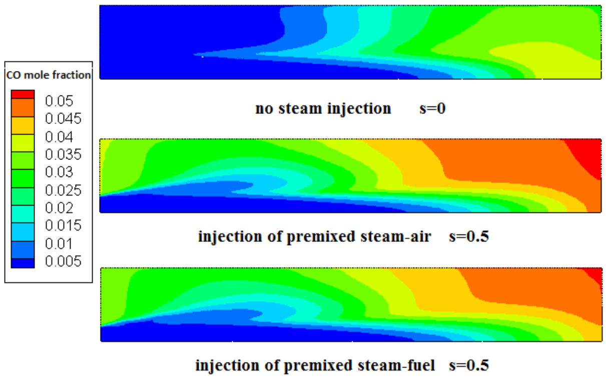

Figure 6. CO mole fraction in combustion chamber for three cases of no steam injection, injection of premixed steam-air and injection of premixed steam-fuel

As the figures show the injection of premixed steam-fuel causes further decrease in NOx and CO production in comparison with premixed steam-air and no steam injection cases.

5- References

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